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ABSTRACT

End-user statistical computing is one way to improve the productivity of researchers; it does so by providing them with a statistical computing environment and with guidance on its appropriate use. Critical success factors include: (1) ease of use; (2) software correctness and robustness; (3) compatibility with system resources; (4) training and education; (5) short-term and long-term consultation; and (6) management sponsorship. Researchers need to know how to use a statistical method; they do not need detailed knowledge of a statistical method's underlying mathematics. With appropriate guidance and contact, researchers can directly control the execution of a statistical method in an appropriate manner. The social payoff is that more scientists, engineers, and technicians can design and analyze experiments with shorter turnaround times than without end-user statistical computing. Future directions involve expert system components of the user interface and incorporation of computer-intensive methods. A 59-item list of references is provided. (SLD)

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END-USER STATISTICAL COMPUTING

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End-user statistical computing offers statisticians a leadership challenge. We increase our contribution when we empower researchers in the use of statistical method. In this paper I define end-user statistical computing, list some factors contributing to its successful implementation, survey the statistician's role made wider through new computer technology, and offer personal observations and suggestions for further reading on preparation for the role.

Background and Definition

Other publications have presented the excitement and personal-growth potential of statistical consulting. The usual setting is a one-on-one mutual-problem-solving engagement between statistician and researcher [Boen & Zahn 1982]. We statisticians often find additional involvement and satisfaction by participating as technical experts on project teams. In both these situations, which I call "traditional consulting," statisticians generate the experimental design or analyze the data. The related function of statistics trainer offers the opportunity to leverage one's expertise through empowering others. In this paper I show how such a facilitating role can be extended for wider impact.

Statisticians know, as do some researchers, that statistical advice often pays for itself many times over. Unfortunately, traditional statistical consulting reaches a small minority of researchers. While statistical training of science and engineering students is improving, many researchers still lack the benefit of professional advice. Frequently they either struggle with their data or use inappropriate designs or analyses. For example, it is unlikely that a researcher would seek a statistician to compute a mean, though statistical advice may be appropriate if the underlying need is to estimate a central tendency. We can ignore or bemoan this deficiency or choose to get involved through popularizing statistical method.

Consider the effect of computing technology innovation. New advances in hardware and software induce a qualitative change in the use of computers: end-user computing. Here are two definitions:

> The use of computing technology in which the end user plays a dominant role in the definition, development, and creation of automated processing and output. [Ball 1987]
>
> [T]hose systems and tools used directly by employees for purposes of manipulating their own data and applications; deciding when and how to use applications; and owning data resources. [Johnson & Rogow 1988]

For additional discussion of the philosophy and practice of end-user computing, refer to Couger [1987], Huff et. al. [1988], Koffler [1987], Radding [1987], Rivard & Huff [1988], Schneiderman [1987], and Sobkowiak [1985].

In their textbook for analytical chemists, Caulcutt and Boddy [1983] assert "...nonetheless that the scientist or technologist can make use of statistics even if [s/]he has very little knowledge of mathematics." In the past, statistical computing entailed the artful arrangement of mathematical computing routines through procedural programming languages, which required an awareness of a) statistical method's mathematical underpinning and b) skills in computer programming. As layered software incorporates statistical methods of broad utility, the focus of statistical computing, for particular experiments, shifts from procedural programming to telling the genie of the disk what method to execute. Recent developments in end-user computing systems and statistical software offer statisticians a leadership opportunity in facilitating others' implementation.

End-user statistical computing is end-user computing in support of researchers' use of statistical method: statistical functionality in an end-user computing environment and guidance on its appropriate use. It is based on the premise that statistical method is not, and should not be, the exclusive property of professional statisticians, but can be developed and used to productive levels by all researchers in the vast array of

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experimental situations which make up their day-to-day living. Under end-user statistical computing, researchers themselves directly control execution of statistical method. The social payoff is that more scientists, engineers and technicians design and analyze experiments with shorter turnaround time.

Success Factors

To fix ideas and identify success factors, I set forth five principles of end-user statistical computing. My point of departure is Kathleen Potosnak's [1988] observation that "The key to increasing end-user productivity is twofold: provide the functions users really need and make those functions easy to use."

These factors promote this mission:

- The researchers' statistical computing environment should feature statistical methods appropriate to their research needs.
- The software should be easy to use.
- Guidance should be provided on the selection of statistical method (both prior to and during data analysis) and interpretation of the statistical computing output.
- The statistical software should function correctly; assurance should be provided that the software design and coding processes correctly implement the algorithms.
- End-user statistical computing resources should be promoted in the research community.

Statisticians' Challenge and Role

The new statisticians' role suggested in this paper augments, but does not replace, traditional consulting. There will always be technically challenging problems requiring hands-on effort from professional statisticians. To realize the potential of end-user statistical computing, the statistician's interaction with the client or client group takes on the character of a helping relationship in which the statistician "has the intent of promoting the growth, development, maturity [and] improved functioning... of the other" [Rogers 1961 Chapter 3].

The first success factor identified in the previous section calls for statistical methods appropriate to the users' needs. We statisticians recommend software to our clients largely on the basis of underlying functionality. These statistical methods are effectively inaccessible unless the software and supporting system make it easy for the user to invoke, and interpret the output from, the selected method. Statisticians may shape a statistical computing environment through direct recommendation of statistical software to individual contributors or indirectly through suggestion to computing-center or research-management decision makers.

Any recommended statistical software must be compatible with the users' existing or planned computing environment. Diversity of end-user computing systems and languages further complicates statistical software selection. Whether this diversity will be attenuated through a market-driven standards shakeout or continue indefinitely is difficult to predict. Statistical software reviews aid in product selection. For an example, refer to PC Magazine Reviewers [1989] and Raskin [1989].

Diversity contends with unification. Much of the controversy in software selection revolves around computer users' strong emotional attachment to their currently-used and diverse computer systems vs. the economizing efforts to migrate to common resources. Sherry Turkle describes the emotions felt towards computers:

> A variety of people, ranging from virtuoso programmers to those whose contact with computers goes no further than playing video games, compare their experiences with computers to sex, to drugs, or to transcendental meditation. The computer's reactivity and complexity stimulate a certain extravagance of description [Turkle 1984].

Use of application software is increasingly a dialogue between the user and the product. Contemporary statistical software interfaces don't fully provide appropriate selection and use of statistical method; responsibility for most selection still rests with the user. Software documentation, both hard copy and online, does provide some guidance though not yet at a satisfactory level for researchers. By influencing the statistical software vendor's choice of product features, statisticians indirectly provide guidance on appropriate use. This influence doesn't come easily; statisticians must cultivate personal working relations with vendor staff and take leadership roles in user groups.

Software products are evolutionary. We consulting statisticians represent our clients to the software vendors when we articulate the need for particular statistical functionality and user friendliness. Vendors offer several communication channels for the statisticians seeking to influence

product development: user surveys, account representatives, user group meetings, technical support hotlines and personal contacts all have their utility. Expert-system mechanisms offer the potential for adding guidance functionality to the user interface [Gale 1986, Harmon & King 1985] but are not yet a part of commercially-available statistical software. Development of such expert systems clearly requires statistical input.

Statisticians familiar with software development may question the vendors' software development processes [Kernighan & Plauger 1978, Ledgard & Chmura 1978, Walton 1986, Weinberg 1971].

Accessibility of statistical method presents the opportunity to proselytize its use. Statisticians add value to researchers' work when they present tutorials, publish newsletters, and facilitate peer-group seminars.

How might an activist statistician introduce end-user statistical computing to a research group? I recommend the role of catalyst for change and a multi-stage strategy.

1. Identify stakeholder groups such as researchers with unmet needs, opinion leaders, risk takers open to new methods, peers whose cooperation is required, manufacturing professionals responsible for product optimization and quality [Majchrzak 1988], the client organization's management, and computer resource vendors.
2. Work with these stakeholders to create a shared understanding, develop a mission, a plan, commitment, concerted action, and fulfillment of the goal.
3. Establish collaborative work relationships with individuals who can contribute.
4. Follow-up the introduction through training and handling questions (short-term consulting).

Skill Development

This facilitation extends the statistician's role in the direction of teacher, coach, salesperson and therapist [Brookfield 1988]. In experiencing this role and developing the skills needed for effective and efficient action, I find the process concept a useful point of view. As mathematics students, for example, we're encouraged to study the problem-solving process -- the process behind the product [Hadamard 1954, Polya 1957]. As applied statisticians we study the science process to clarify our clients' needs [Beveridge 1957]. We interact with clients through a consulting process [Block 1981, Boen & Zahn 1982, Weinberg 1985].

We choose to concern ourselves with others' problems. The easiest people to work with are those healthy individuals open to new ideas and eager for supportive resources. Typically, the first skills we exercise here are friendly relationship building [Coleman & Edwards 1979]. Going beyond dyadic relations, we broadcast our ideas through group presentation [Carnegie 1962, Leech 1982] and influence by example [Weinberg 1986]. As participants or teachers we can facilitate group decision making [Doyle & Straus 1976, Fisher 1980, Mosop 1988]. We have a greater impact when we develop a vision shared by others and achieve commitment to realizing the vision [Bennis 1989, Cohen & Bradford 1990, Greenleaf 1977, Leonard-Barton & Kraus 1985, Metz 1986]. It's important to maintain awareness of diversity of thinking among the professional disciplines [Schon 1983] and communication channels with peers and supervisors [Boe & Youngs 1989, Scheele 1979].

As technically nonstandard problems add complexity and challenge, so do emotional dynamics and semantic barriers in changing others' work patterns. The tough, fuzzy problems of end-user statistical computing revolve around communication and influence. In this domain, emotional overlay overshadows rational sequence. I suggest that the statistician considering venturing into this area begin with self-scrutiny, examining one's own motives and the interplay between one's thoughts and feelings. [Ellis & Harper 1975, Greenleaf 1977 Chapter 1, Robert 1982, Rogers 1961 Chapter 3]. As statisticians we may promote decision-making in the presence of uncertainty; as change agents we may promote improvement in the presence of dysfunctional thinking and behavior. We must develop skills in overcoming commonplace emotional barriers [Bolton 1979, Nirenberg 1984, Sinetar 1988, Stokes 1989]. Dealing with difficult people comes with the territory [Bramson 1981, Bross 1975, Elgin 1987], and not infrequently in today's organizational climate we must come to terms with more flagrant compulsive/addictive behavior [Bradshaw 1988, p.5, Goleman 1985, Lareau 1985] and personality disorder [Kets de Vries 1989]. As in the technical domain, it pays to develop a toolkit of pragmatic techniques.

For those willing to take the plunge, end-user statistical computing offers a highly rewarding challenge.

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